Chapter 7

Noise and Vibration in Army Aviation

Aircraft, both rotary and fixed wing, produce perhaps the most severe noise and vibration environments experienced by aircrew members. These biomechanical force environments, singly and in combination, threaten the health, safety, and well-being of people associated with or exposed to aircraft operations. Mechanical vibration transmitted to human operators can induce fatigue, degrade comfort, interfere with performance effectiveness, and under severe conditions, influence operational safety and occupational health. Excessive exposure to airborne acoustic energy may interfere with routine living activities, induce annoyance, degrade voice communication, modify physiological functions, reduce the effectiveness of performance, and cause noise-induced hearing loss. Both noise and vibration effects may occur simultaneously with the initial exposure or may be manifested only after the passage of time and repeated exposure. The impact of most exposures can be minimized by focusing on the source, the propagation of the energy, and the exposed crew member. Monitoring the influence of such exposures over time with hearing tests and medical observations can also determine the impact of these combined factors. This chapter addresses the physiology of both noise and vibration and ways to minimize their short-term and long-term exposures. Aircrew members must use their knowledge and training to protect themselves and to prevent injuries caused by noise and vibration.

NOISE CHARACTERISTICS AND EFFECTS

7-1. Noise is sound that is loud, unpleasant, or unwanted. Vibration is the motion of objects relative to a reference position, which is usually the object at rest. In aviation, both may cause annoyance, speech interference, fatigue, and hearing loss.

ANNOYANCE

7-2. Noise energy is undesirable when attention is called to it unnecessarily or when it interferes with routine activities in the home or while flying an aircraft. Individuals become annoyed when the amount of interference becomes significant. High-frequency noises and vibration are especially irritating and can cause a subjective sense of fatigue.

SPEECH INTERFERENCE

7-3. When noise and vibrations reach a certain loudness or amplitude, they mask normal speech communication. Thus, words become difficult to understand.

HEARING LOSS

7-4. The most important and common undesirable effect of noise is permanent hearing damage. Excessive vibrations can manifest themselves in terms of internal organ malfunctions and skeletal disabilities. Damage may be rapid when noise is either extremely intense or prolonged. More often, it is insidious in onset and results from continual exposure at lesser intensities. All aviation personnel need to recognize that the damage may become permanent.

SOUND AND VIBRATIONAL MEASUREMENT

7-5. Sound and vibration energy have measurable characteristics. These characteristics are frequency, intensity (or amplitude), and duration.

FREQUENCY

7-6. Frequency is the physical characteristic that gives a sound the quality of pitch. Frequency of periodic motion is the number of times per second that the air pressure oscillates. The number of oscillations, or cycles per second, is measured in hertz.

Human Hearing and Speech Range

7-7. The human ear is very sensitive and can detect frequencies from 20 to 20,000 hertz. Speech involves frequencies from 200 to 6,800 hertz, the range in which the ear is most sensitive.

Speech Intelligibility

7-8. People must be able to hear in the range of 300 to 3,000 hertz to understand speech communication. Speech outside these ranges may result in incoherence or misinterpretation.

Vibration

7-9. Vibration affects the body most in low frequencies, usually confined to frequency ranges below 100 hertz to displace body parts. These effects vary greatly with the direction, body support, and restraint.

INTENSITY/AMPLITUDE

7-10. Intensity is a measure that correlates sound pressure to loudness. Amplitude (for vibration) is the maximum displacement about a position of rest.

7-11. Aviation personnel need to understand the relationship of decibels to sound pressure (vibration). For every 20-decibel increase in loudness, sound pressure increases by a factor of 10. At 80 decibels, sound pressure is 10-thousand times greater than at 0 decibel; at 100 decibels, sound pressure is one-million times greater than at 0 decibel. The same sound pressure moving through the air that stimulates the ear to hear may also cause hearing loss under certain conditions. Table 7-1 shows the effects of various sound intensities on listeners.

Table 7-1. Effects of Various Sound Intensities on the Listener

Frequency (Db)	Effect
0	Threshold of Hearing
65	Average Human Conversation
85	Damage-Risk Limit
120	Threshold of Discomfort
140	Threshold of Pain
160	Eardrum Rupture

DURATION

7-12. Duration is the length of time that an individual is exposed to noise or vibrations. It is a variable factor that may be measured in seconds, minutes, hours, or days or any other selected unit of time.

NATURAL BODY RESONANCE

7-13. Natural body resonance is the mechanical amplification of vibration by the body occurring at specific frequencies. Table 7-2 shows resonant frequencies for various parts of the human body.

Table 7-2. Resonant Frequencies for Various Parts of the Human Body

Body Part	Resonant Frequency (Hz)
Whole Body	4–8
Shoulder Girdle	4–8
Head	25
Eyes	30–90

DAMPING

7-14. Damping is the loss of mechanical energy in a vibrating system. This loss causes the vibration to slow down.

NOISE AND HEARING LEVELS

7-15. Army aviation personnel are exposed to two types of sound levels that can impair their hearing. The sound levels that affect the duration of noise exposure are steady-state noise and impulse noise.

STEADY-STATE NOISE

7-16. Aviation personnel encounter this type of continuous noise around an operating aircraft. The noise is usually at a high intensity over a wide range of frequencies. The Surgeon General has established 85 decibels, at all frequencies, as the maximum permissible sound level for continuous exposure to steady-state noise (damage-risk criteria). There is a direct link between duration of exposure and intensity; the louder the sound, the shorter the time required to cause hearing loss. Table 7-3 shows the recommended allowable sound intensities for the various durations of exposure. *Exposure to noise above recommended duration levels could result in noise-induced hearing loss*—the primary risk to Army aviators.

Table 7-3. Recommended Allowable Noise-Exposure Levels

Exposure Duration Per Day (hr)	Maximum Exposure Level (db)
8	85
4	90
2	95
1	100
1/2	105
Note: For every 5-decibel noise intensity increase, the exposure time limit is cut in half.	

IMPULSE NOISE

7-17. Weapons fire produces this type of noise. It is an explosive sound that builds rapidly to a high intensity and then falls off rapidly. Although the entire cycle usually lasts only milliseconds, this sound is detrimental to hearing when the intensity exceeds 140 decibels.

7-18. Looking at Army aircraft as both fixed and rotary wing, certain generalizations can be made. Overall noise levels generally are equal to 100 or more decibels. This level exceeds the average 85-decibel damage-risk criteria. Table 7-4 shows the estimated noise levels for both rotary- and fixed-wing Army aircraft.

Table 7-4. Rotary-Wing and Fixed-Wing Aircraft Noise Levels

Aircraft	Noise Level (dB)
UH-1H	102
AH-1S	105
OH-58C	103
OH-58D	100
CH-47D	112
UH-60A	108
AH-64	104
TH-67*	102
C-12 / RC-12	106**
UC-35	96***
* Based on a Bell 206 helicopter ** Exterior noise level, *** Cabin noise level	

7-19. The frequency that generates the most intense level is 300 hertz. Low-frequency noise will produce a high-frequency hearing loss. Providing adequate hearing protection for lower frequencies is very difficult. Exposures to these levels without hearing protection will cause permanent, noise-induced hearing loss.

VIBRATIONAL EFFECTS

7-20. The human body reacts in various ways to vibration:

- Vibration can cause short-term acute effects because of the biomechanical properties of the body.
- The human body acts like a series of objects connected by springs.
- The connective tissue that binds the major organs together reacts to vibration in the same way as springs do.
- When the body is subjected to certain frequencies, the tissue and organs will begin to resonate (increase in amplitude).
- When objects reach their resonant frequencies, they create a momentum, which increases in intensity with each oscillation.
- Without shock absorption, vibration will damage the mass or organ.

7-21. Helicopters subject aircrew members to vibrations over a frequency range that coincides with the resonant frequencies of the body (Table 7-5). Prolonged contact with vibration causes short-term effects, as well as long-term effects, to the body. Minor amplitudes of the vibration and the ability of the body to provide some dampening are reasons why humans do not receive injuries every time they fly. Vibration can affect the respiratory system as well as cause—

- Motion sickness.
- Disorientation.
- Pain.
- Microcirculatory effects.
- Visual problems.

Table 7-5. Vibration Frequency Levels for the UH-1 Helicopter

Component	Frequency (Hz)
Engine	110
Main Rotor	4–11
Tail Rotor	30–60

HEARING LOSS

7-22. Such factors as age, health, and the noise environment cause hearing loss. There are three types of hearing loss: conductive, presbycusis, and sensorineural.

CONDUCTIVE

7-23. This type of hearing loss occurs when some defect or impediment blocks sound transmission from the external ear to the inner ear. Wax buildup, middle-ear fluid, and calcification of the ossicles can all impede the mechanical transmission of sound. A conductive hearing loss affects mainly the low frequencies. In most cases, this type of hearing loss can be treated medically. A hearing aid is often beneficial because the inner ear can still pick up sounds if they are loud enough. The aviator may fly with a hearing aid if he or she is given a waiver to continue on flight status.

PRESBYCUSIS

7-24. This type of hearing loss usually results from old age. The hair cells of the cochlea become less resilient as people age.

SENSORINEURAL

7-25. Sensorineural hearing loss occurs when the hair cells of the cochlea are damaged in the inner ear. The primary cause is noise exposure, but disease or aging also can cause this type of hearing loss. Sensorineural hearing loss caused by noise exposure usually occurs first in the higher frequencies. In some cases, a hearing aid may benefit, but generally, no known medical cure exists for this type of hearing loss.

MIXED

7-26. A crew member may have an ear infection that could cause conductive hearing loss and have been diagnosed with a senorineural hearing loss. The ear infection is treatable; sensorineural hearing loss is not.

HEARING PROTECTION AND REDUCTION OF VIBRATIONAL THREAT

INDIVIDUAL RESPONSIBILITY

7-27. Pilots, aircrew members, ground-support troops, and passengers should wear hearing protection at all times. Hearing loss is one hazard of the aviation environment that adequate protective measures can minimize.

7-28. The amount of sound protection that a protective device provides is determined by its fit and condition and, most importantly, by the willingness and ability of the individual to use it properly. Using individual devices in combination provides the best hearing protection.

7-29. While individual devices are not foolproof, virtually all noise-induced hearing loss is preventable if these devices fit properly and are worn on all flights. Even if hearing has already been affected somewhat, these devices will help prevent further damage. Hearing protection is ultimately each individual’s responsibility.

PROTECTIVE DEVICES

7-30. Aircraft noise levels interfere with the speech communication of Army aircrew members and pose the risk of hearing loss. Protective measures can reduce the undesirable effects of noise. These measures include—

- Use of personal protective measures.
- Isolation or distancing of crew members from the noise source.

Helmets

7-31. The HGU-56P (Figure 7-1) and SPH-4B (Figure 7-2) aviator helmets are excellent means of personal protection from the standpoint of noise and crash attenuation. The helmets, designed primarily for noise protection, provide noise attenuation exceptionally well in the range of 3,000 to 8,800 hertz.

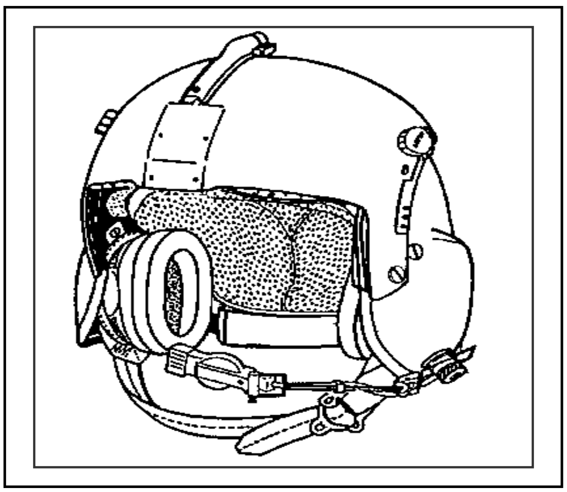

Figure 7-1. HGU-56P Helmet

Figure 7-2. SPH-4B Flight Helmet

7-32. When worn alone, the SPH-4B and the HGU-56P helmets reduce the noise exposure to safe limits for every aircraft in the Army inventory except for the UH-60 (Black Hawk) and CH-47 (Chinook). Table 7-6 shows the estimated attenuation levels for various types of helmets. The UH-60 and CH-47 aircraft require both helmet and earplug use to attenuate noise and prevent hearing loss.

7-33. Ancillary devices worn with the aviator's helmet can significantly compromise hearing protection. For example, eyeglass frames break the ear seal, creating a leak and producing a sound path from outside to inside the earcup.

Table 7-6. Estimated Attenuation Levels for Helmets and Other Protective Devices

Aircraft	Hearing Protector	Effective Exposure Level (dB)
AH-1S	HGU-56 SPH-4B SPH-4	77.0 77.4 83.2
UH-1H	HGU-56 SPH-4B SPH-4	81.3 81.0 85.9
OH-58D	HGU-56 SPH-4B SPH-4	81.6 81.5 86.3
OH-58C	HGU-56 SPH-4B SPH-4	76.9 76.8 81.4
UH-60A	HGU-56 SPH-4B SPH-4	90.6 90.6 95.1
CH-47D	HGU-56 SPH-4B SPH-4	86.8 88.0 93.4
AH-64	IHADSS (REG) IHADSS (XL)	80.2 83.5
C-12	H-157 Headset	70.5

Communications Earplug

7-34. The communications earplug, Figure 7-3, improves hearing protection and speech-reception communication. The device includes a miniature transducer that reproduces speech signals from the internal communication system. The foam tip acts as a hearing protector, similar to the yellow-foam earplugs that pilots wear for double hearing protection. A miniature wire from the CEP connects to the ICS through the mating connector mounted on the rear of the helmet. The CEP has recently been issued its AWR for all U.S. Army aircraft using the SPH-4B or HGU-56P helmets and for the M45 ACPM for all U.S. Army aircraft using the M24 mask. The tested pilot population has enthusiastically received this communication device. This product is not yet in the federal stock system. For more information on this product, contact the U.S. Army School of Aviation Medicine at DSN 558-7680.

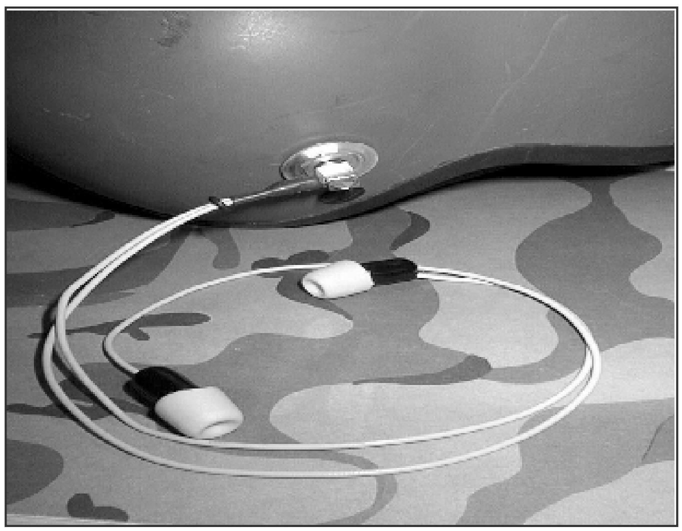

Figure 7-3. Communications Earplug

Earplugs

7-35. **Insert-Type Earplugs.** Insert-type earplugs are among the most common types of hearing protection now in use. Earplugs need to be comfortable if they are to do their job. All earplugs tend to work loose because of talking or vibration and need to be reseated periodically to prevent inadvertent noise exposure. With properly fitted earplugs, users' voices will sound lower and muffled, as if they were talking inside a barrel. Noise protection with earplugs is 18 to 45 decibels across all frequency bands. Earplugs may come in three different types: the E-A-R® foam earplug, the V-51R single-flange earplug, and the SMR triple-flange earplug. Wearing earplugs for the first time in the cockpit may diminish the ability to hear communications in the cockpit. Crew members may feel that they have to concentrate and listen more closely to the transmissions. Once they get used to listening with the earplugs in place, crew members will find it easier to hear speech communication.

7-36. **E-A-R® Foam Earplug.** The E-A-R® yellow-foam earplug has three qualities: it excels in noise attenuation, comfort, and ease of maintaining a seal. To ensure maximum attenuation, these plugs should be kept clean and inserted properly.

7-37. **V-51R Single-Flange Earplug.** The V-51R single-flange earplug comes in five different sizes for better fit. Different sizes (extra small, small, medium, large, and extra large) provide a suitable fit for more than 95 percent of all Army aviation personnel. About 10 percent of aircrew members need a different size of earplug for each ear. The single-flange earplug may be cleaned with soap and water.

7-38. **SMR Triple-Flange Earplug.** The SMR provides about the same attenuation as the V-51R. Triple-flange earplugs come in three sizes (small, medium, and large). This earplug is comfortable for most individuals. This earplug may be cleaned with soap and water.

Combined Hearing Protection

7-39. The polymeric foam (E-A-R®) hand-formed earplug—in combination with the SPH-4B, HGU-56, and IHADSS helmets—will provide additional protection from noise generated by *all* aircraft in the U.S. Army inventory. Table 7-7 shows exposure levels for various aircraft when the pilot wears the SPH-4 helmet with each of the three types of earplugs at the pilot's station.

Table 7-7. Attenuation Levels for Protective Helmets and Earplugs

Protector	UH-60A (120 knots)	CH-47D (100 knots)	AH-1S (100 knots)	OH-58 (100 knots)	UH-1H (100 knots)
SPH-4 with triple-flange plug	72.6	77.5	70.2	65.7	70.7
SPH-4 with single-flange plug	75.3	78.4	71.5	67.4	71.9
SPH-4 with foam plug	70.4	77.3	68.8	63.5	68.8

Note: SPH-4B helmet attenuation levels when worn with earplugs are 1 to 2 decibels lower for each aircraft indicated above. HGU-56 helmet attenuation levels when worn with earplugs are 2 to 3 decibels lower for each aircraft indicated above.

Earmuffs

7-40. Several types of earmuffs (Figure 7-4) provide adequate sound protection for ground-support aviation personnel. Most earmuffs that are in good condition and properly adjusted will attenuate sound as well as properly fitted earplugs. The earmuffs tend to give slightly more high-frequency protection and slightly less low-frequency protection than earplugs.

PREVENTIVE MEASURES

7-41. Vibration cannot be eliminated, but its effects on human performance and physiological functions can be lessened. Various preventive measures can be taken to reduce the effects of vibration:

Figure 7-4. Earmuff

- Maintain good posture during flight. Sitting straight in the seat will enhance blood flow throughout the body.
- Restraint systems provide protection against high-magnitude vibration experienced in extreme turbulence.

CAUTION

Body supports, such as lumbar inserts and added seat cushions, reduce discomfort and can dampen vibration; however, during a crash sequence they may increase the likelihood of injury because of their compression characteristics. Do not modify the aircraft seats for the sake of comfort.

- Maintain your equipment. Proper aircraft maintenance, such as blade tracking, can reduce unnecessary vibration exposure.
- Isolate the aircrew members or passengers. When loading patients on MEDEVAC aircraft, remember that patients placed on the floor will experience more vibration than those in the upper racks.
- Limit your exposure time. Make short flights with frequent breaks, rather than one long flight, if the mission permits.
- Let the aircraft do the work. Do not grip the controls tightly. Vibration can be transmitted through control linkages during turbulence.
- Maintain excellent physical condition. Fat multiplies vibration while muscle dampens vibration. Strong muscles act to reduce the magnitude of oscillations encountered in flight (damping). An overweight aircrew member is more susceptible to decrements in performance and the physiological effects of vibration.
- Maintain good physical condition to lessen the effects of fatigue. Being in good physical condition permits you to continue to function during

extended combat operations with minimum rest. Energy and alertness keep you alive.

- Maintain sufficient hydration. Drink plenty of fluids, even if you do not feel thirsty: a minimum of two quarts of water in addition to fluids taken with meals. Dehydration, coupled with vibration, can cause fatigue twice as fast and double the time needed for recovery.